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Shunts and Inductors for Surge-Current Measurement

Improvements in recent years in the design of electric power systems and their component parts—such as transformers, lightning arresters, and circuit breakers—have reduced power failures from lightning to a small but still annoying number. These new developments have been made possible by the use of surge generators, which enable man to produce in the laboratory electrical surges having the same voltage and current magnitudes as those occurring on transmission lines as a result of natural lightning. Techniques in this field have advanced to the point that most manufacturers of high-voltage equipment now maintain high-voltage and high-current surge generators and measuring equipment in their laboratories both for development testing of insulation designs and for routine tests on equipment for high-voltage networks.

So that data thus obtained may be used to best advantage in the over-all design of a power system, surge-measurement methods must give equivalent results in all surge testing laboratories and should provide as accurate a picture as possible of the actual surge. However, the satisfactory measurement of surge currents presents peculiar difficulties because of the high values of impulse current—up to 200,000 amperes—attained in a matter of millionths of a second and because of the high-frequency components of the surge current. The National Bureau of Standards is therefore seeking to develop better methods of surge measurements and to assist in the standardization of surge testing. An important phase of the work, conducted by John H. Park of the electrical instruments laboratory has been the developments of shunts and mutual inductors[1] for measuring the magnitude and rate of change of surge currents.

High-current surges are obtained by discharging a bank of capacitors, previously charged to a high potential, through a low-impedance path consisting of the test specimen and the measuring equipment. They are usually measured by inserting a low-resistance shunt in the discharge circuit and applying the voltage drop across this shunt to a high-speed cathode-ray oscillograph, which gives a record of the wave shape and magnitude of the voltage drop. For this measurement to be capable of simple interpretation in terms of current, the voltage drop across the shunt must be proportional to the current through it, and the proportionality factor must be the same for various types of current surges and for all values of current during the surge. This requires the shunt to have (1) low residual inductance; (2) minimum inductive pick-up from stray magnetic fields; (3) sufficient mass to absorb the heat energy developed in it during the surge without a temperature rise that would affect its resistance, dimensions, and strength; (4) sufficient mechanical strength to withstand deformation by forces associated with the magnetic field of the large momentary current; and (5)

[1] For further technical details, see Shunts and inductors for surge current measurements, by John H. Park, J. Research NBS **39**, 191 (1947) RP1823.

negligible "skin effect" (crowding of the current to the outer layers of the shunt walls) for frequencies up to several megacycles per second.

After a rather complete theoretical comparison of the various types of shunts that might fulfill these requirements, it was concluded that a shunt consisting of two coaxial tubes, with the potential-measuring circuit brought out as a coaxial cable from the smaller tube, would be most satisfactory for surge-current measurements. Two shunts of this type have been constructed and used at the Bureau. Advantages of the coaxial tubular design include a more nearly constant impedance over a wide frequency range, minimum inductive pick-up from current-carrying parts of the surge generator, and freedom in location of ground connections at the surge generator.

Two general types of shunts, the coaxial tubular form and the flat strip, were considered in the analysis, since both lend themselves to computations of inductance and skin effect. Otherwise, the evaluation of various types of shunts would have required the actual construction of a large number, with subsequent experimental comparisons. To compare the constancy of effective impedance for variable frequency in the tubular and flat-strip shunts, typical designs of each were assumed, and the inductance and skin effect computed from the appropriate formulas.

The tubular shunt was found to have a much lower time constant than the flat strip, indicating that its reactance would be negligible over a higher frequency range. The skin effect at 1 megacycle was apparently the same for both shunts, but the formula used in obtaining the skin effect for the strip shunt neglected edge effects (concentration of the current on edges), which are known to increase the skin effect considerably at high frequencies. Thus it appeared that the tubular shunt, since it has no edge effects, would have less change in effective impedance at high frequencies than the strip shunt. The analysis showed that a decrease in both inductance and skin effect could be obtained by going to thinner strips or thinner-walled tubes, but that this procedure could not be carried too far because of the heat-capacity requirements of the shunt. In any case, an improvement made by this means in the strip shunt could probably also be made in the tubular shunt.

TECHNICAL NEWS BULLETIN

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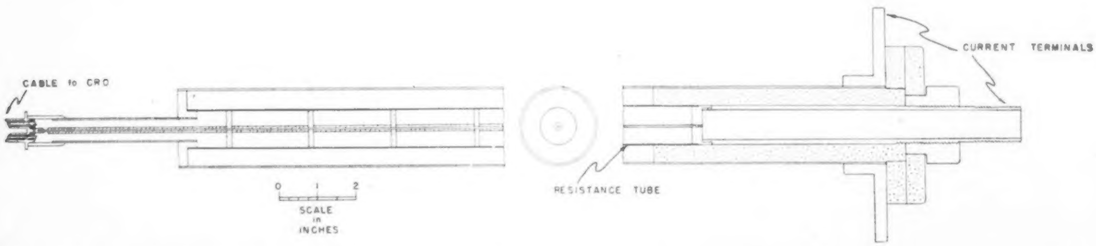
Contents

The rate of change of current in the discharge circuit of the surge generator at the Bureau may be as great as 5×10^{10} amperes per second, in which case a very small pick-up loop in the potential measuring circuit might easily have sufficient mutual inductance to induce an electromotive force of more than 100 volts in the potential circuit. The extreme importance of minimizing mutual inductance between the potential circuit and all current-carrying parts is thus apparent.

The potential circuit of a tubular shunt may be considered as an extension of the coaxial cable from the cathode-ray oscilloscope, ending in a direct short circuit from the central conductor to the sheath. Because of

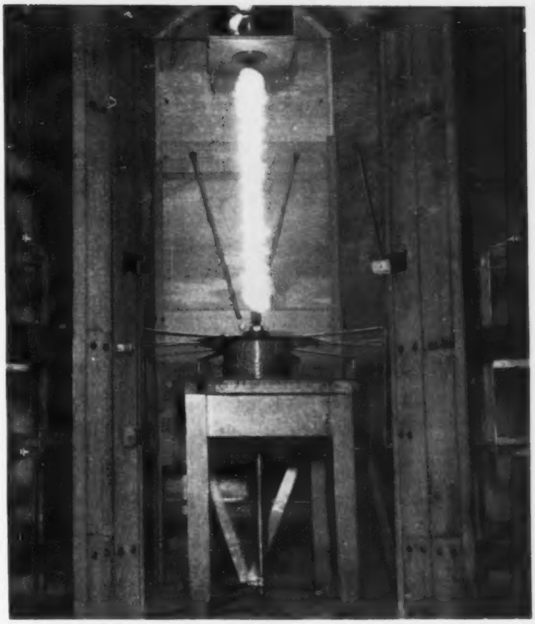


The resistance element of the coaxial tubular shunt is a resistance tube connected to a cathode-ray oscillograph by means of a coaxial cable. Uniform distribution of the current in the shunt is insured by the coaxial arrangement and by extending the tubular current leads several diameters beyond their junctions with the cathode-ray-oscillograph (CRO) leads. This particular shunt is designed for currents from 50,000 to 200,000 amperes, and smaller shunts are used for currents below 50,000 amperes.

the axial symmetry of this arrangement, the mutual inductance between the potential circuit and any current-carrying parts is the lowest that can be obtained. Even when the sheath of the cable is connected to ground so that ground currents flow in the cable sheath and in the outer current-return tube, or the shunt itself, these ground currents will not induce voltage in the potential circuit, provided the density of such current is symmetrical about the shunt axis. In the shunts constructed at the Bureau, concentration of current along one side of the shunt was largely eliminated by extending the two tubes forming the current leads several diameters beyond their junctions with the potential leads. Although a strip shunt could be built with very low inductive pick-up between its potential circuit and current-carrying parts, the tubular design alone offers the possibility of entirely eliminating these effects.

For many experiments involving high-current surges, it is desirable to know the rate of change of current with time. This information is obtained at the Bureau by use of a mutual inductor. The primary of the mutual inductor is connected in the heavy-current discharge circuit, and its secondary is connected to the oscilloscope. The voltage record obtained on the oscilloscope is then a function of the rate at which the current is changing and of the known mutual inductance of the inductor. To be suitable for this purpose a mutual inductor must have a low mutual inductance (about 0.05 microhenry) computable from its dimensions, and its effective inductance should be constant for frequencies up to 50 megacycles per second or higher.

As no previously known design of mutual inductor would fulfill these requirements, a coaxial tubular mutual inductor was designed at the Bureau, and a 0.05-microhenry inductor of this design was constructed. Essentially, it consists of two coaxial tubes of conducting material connected by a radial conduction ring. The inner tube constitutes the primary of the mutual inductor, and the secondary consists of the shorter outer tube, the portion of the inner tube within the outer tube, and the connecting ring. As in the case of the shunt, the coaxial tubular construction tends to minimize inductive pick-up from any magnetic fields that may be present. This type of inductor should also prove useful in other applications requiring measurements at high frequency.



A 100,000-ampere current surge is measured during discharge by means of a coaxial tubular shunt (beneath the table) developed at the Bureau. The current magnitude is determined from the characteristics of the voltage drop across the shunt as recorded on a high-speed cathode-ray oscillograph.

Strain Tester for Rubber

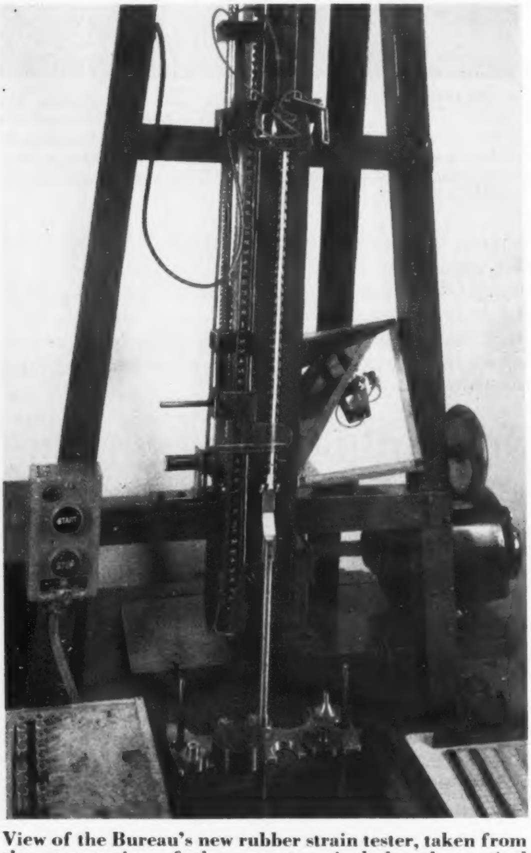
A new device developed in the Bureau's rubber laboratory conveniently measures *strain* in vulcanized rubber, in contrast to the conventional tensile testers that determine tensile *stress*. In this apparatus the strain is measured at a definite time after application of a predetermined stress, while the usual testing method employs essentially the opposite procedure, that is, measurement of stress at a specified strain. Designated therefore a "strain tester," its development followed Bureau investigations that revealed that the new technique combines a higher degree of reproducibility in measurement with an accuracy not previously possible. These investigations were part of a program conducted for the Office of Rubber Reserve on the improvement of physical testing methods for synthetic rubbers.

During the past 3 years, both strain and tensile tests have been made at the Bureau on several hundred sheets of various lots of GR–S, GR–I, and GR–M synthetic rubbers. Statistical analyses of these data have shown that variances introduced by the strain test are negligible compared to the variances in different sheets of rubber from the same batch, or in batches from the same lot of polymer. On the other hand, differences introduced by the usual measurements of stress at a specified elongation are of the same order of magnitude as those for different sheets and different batches.

Since 20 specimens for the strain test can be cut from a single test sheet, it has now become possible to detect differences in the properties of rubber from different parts of the sheet, or to study the effect of aging on stiffness or modulus by means of a single test sheet. Furthermore, the relatively great distance between bench marks on the specimens used in the new test and the fact that the test subjects them to a uniform stress for a definite length of time, make these specimens desirable for measurements of set. Values determined in this manner are found to be much more reproducible than measurements made after rupture of the specimen.

The strain tester was designed to incorporate this improved reproducibility of measurements and high degree of accuracy in an apparatus suitable for routine testing. The design features responsible for the precision and accuracy are observation of bench marks when they are essentially at rest, use of freely suspended weights to attain the desired stress without frictional effects, and increase in the distance between bench marks of four times that employed for the usual dumbbell-shaped specimens. In addition, the various manual operations in the test are simplified.

The tester is composed of two parts, built into a supporting table. One part, above the table, includes a mechanism for extending the specimen, an optical system for observing the upper bench mark on the specimen from a seated position, a mechanism for alining a millimeter tape with the bench marks, a time cycle controller for regulating the sequence of operations, and a keyboard for selecting the load to be applied to the specimen. Beneath the table is the mechanism for applying the selected load. This mechanism employs eight solenoids for adding eight different weights singly or in combination to a weight assembly attached to the specimen.



View of the Bureau's new rubber strain tester, taken from the perspective of the operator, includes the optical prism, the rubber specimen in test position, the mirror in which the upper level mark is observed, and the weight-selector keyboard.

The rubber specimens are strips 0.254 inch wide and 6 inches long, cut from the usual 6-inch square test sheet. The specimen die consists of six razor blade strips clamped between metal spacers. Thus, five specimens are cut in a single operation. The bench marks, placed on the specimens in the usual manner, are spaced 10 centimeters apart. Using a special thickness gage, the average thickness of the specimen between the bench marks is obtained by a single measurement. The gage reading is entered on the keyboard of the strain tester.

After placing the specimen in the grips, the starting switch is pressed, causing the selected weights to be added to the weight assembly and starting the motor, which pulls the specimen upward. When the specimen lifts the weight assembly from its support, a switch starts the time-cycle controller. At subsequent predetermined intervals this controller (1) halts the upward travel of the specimen by stopping the motor when the weight assembly has been lifted sufficiently to prevent it from coming back to rest on its base as the specimen continues to stretch, (2) signals the operator and lights the lamps in the optical system for observing the upper bench mark and hair line, (3) extinguishes the lamps to prevent late observations, (4) returns the specimen and weights to their starting positions by starting the motor in the reverse direction, and (5) stops itself at the end of the cycle.

The strain test is not intended to measure stress-strain properties near or at rupture. For control testing, however, and for much research, a knowledge of the strain for any stress below the region of rupture is sufficient. The improved precision obtained in the strain test warrants a separate determination of the stress and strain at failure where necessary.

An examination of strain data, plotted as a function of the time of cure, reveals a rectangular hyperbola of the form

$$(x-A)\ (y-B) = C.$$

This observation suggests that strain at a fixed stress decreases with time of cure according to the laws of a second-order reaction, and therefore strain is a direct measure of the degree of vulcanization. If t, the time of cure, be substituted for x, and E, the strain or percent elongation, for y, the parameters A, B, and C may be interpreted as vulcanization parameters. In this interpretation A is associated with t_0, the time of impending cure or "scorch time"; B with $E\infty$, the elongation for infinite cure or a structure factor; and C with $1/k$, where k is the reaction rate constant. In the case of materials like GR–M, GR–I, or natural rubber, which crystallize on stretching, the scorch time t_0 becomes smaller at stresses where crystallization begins and becomes negative for greater stresses. It is also noted that these parameters are greatly affected by small variations in the test data. Since data from different test sheets of the same compounded batch and data from different batches of the same lot of polymer show rather large variances, several batches must be tested in order to obtain sufficient data for reliable parameters.

Zeeman Effect of Neutral Nitrogen and Oxygen

Excited atoms of the chemical elements emit radiations of various frequencies depending on the initial and final energy states between which the radiative process occurs. The total number of radiations that an atom is capable of emitting is its spectrum, each individual radiation being called a spectrum line. When the radiative process occurs in a magnetic field, the energy states of the atom become complex so that previously single lines now are separated into an array of closely spaced lines of different intensities, symmetrically grouped about the undisturbed position of the line. This array, or magnetic pattern, known as the Zeeman effect, uniquely identifies the energy levels between which the radiative transition occurs. It furnishes for each energy level a numerical quantity called its g-value or splitting factor.

When the Zeeman patterns of such metals as molybdenum, tantalum, and manganese, are photographed in the red and infrared regions of the spectrum, there usually appear also on the spectrograms the patterns of atmospheric nitrogen and oxygen. The relative positions and estimated intensities in the magnetic patterns of these lines have now been determined for the first time from precise measurements of spectrograms by Dr. C. C. Kiess of the Bureau and Dr. George Shortley of Ohio State University.

Because the multiplet levels of these elements are very close to each other, the effect of the magnetic field is to displace the component levels from their positions of symmetry about the undisturbed position by amounts depending on numerical quantities, or quantum numbers, associated with the levels. As a consequence of this influence, known as the Paschen-Back interaction, the magnetic patterns of the lines are distorted out of their patterns of symmetry. In the case of nitrogen the distortions are slight; but in the case of oxygen they are so pronounced that the pattern bears no resemblance either to that of a weak field or to the triplet that results from complete Paschen-Back interaction.

The interpretation of the measurements of Kiess and Shortley has afforded an interesting application of the quantum theory to the elucidation of the Paschen-Back effect. The g-values derived for the nitrogen and oxygen energy levels are the first to be announced for neutral atoms of atomic number less than 10, or neon, and are found to conform with those required theoretically for the lighter chemical elements.

National Electrical Safety Code

The first five parts of the fifth edition of the National Electrical Safety Code, previously issued separately as National Bureau of Standards Handbooks H31 to H35, are now available in one 408-page cloth-bound volume as NBS Handbook H30*. Each of these parts has been approved by the American Standards Association as an American Standard. The National Electrical Safety Code is now used by over half of the States in their power transmission requirements, as well as by municipal governments, electric power companies, telephone and telegraph systems, and railways.

The page numbers of the separate handbooks have been retained in the new compilation to assist in the location of specific code rules regardless of the volume used, and a complete index is provided. Installation and maintenance rules for electric supply stations are given in part 1; for electric supply and communication lines (including strength requirements for overhead lines and their supports in all parts of the United States, based upon a long-range study of local wind velocities and weather conditions favoring ice accumulation on wires), in part 2; and for electric utilization equipment in part 3. Part 4 contains safety rules for the operation of electric equipment and lines, and part 5 covers radio installations.

Coefficients for Obtaining First Derivative

A 20-page table of coefficients for obtaining the first derivative without differences, prepared by the Bureau's Computation Laboratory, permits calculation of the derivative at a point within a tabular interval by a single machine operation. This table will be of value in many fields of applied mathematical computation where it is desirable to find the derivative of a function that is tabulated at uniform intervals. It will be particularly useful in the location of maxima and minima, in thermodynamic calculations where many functions are found as derivatives of other known functions, and in ballistic computations for slopes of trajectories. The table has been published as the second in the Bureau's new Applied Mathematics Series of publications.*

Exact values of the polynomial coefficients $C_i^{(n)}(p)$ are given for p ranging from $-[(n-1)/2]$ to $[n/2]$. For $n=4$, 5, and 6, the coefficients are tabulated at intervals of 0.01; for $n=7$, they are tabulated at intervals of 0.1. No table is necessary for $n=3$ as the coefficients may be obtained by means of a simple formula.

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*Order these publications only from the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C.; AMS2, Tables of Coefficients for Obtaining the First Derivative Without Differences, 15 cents; H30, National Electrical Safety Code, $1.25.

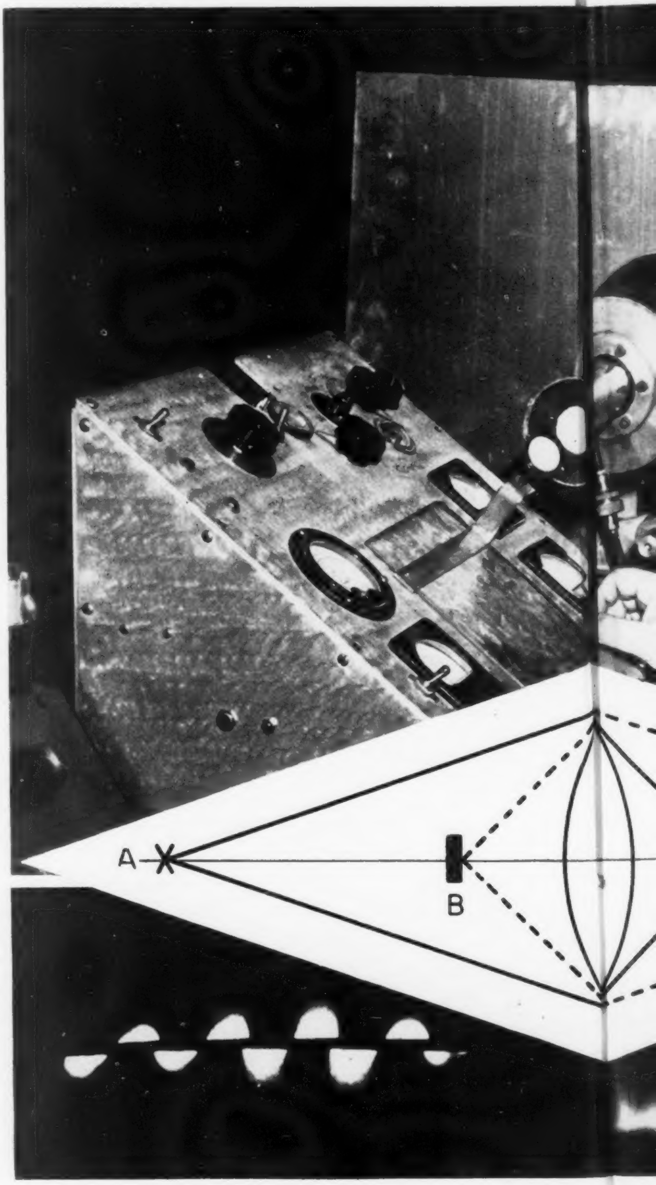
Electron Optic Schl

Electron-microscope experiments conducted by Dr. L. L. Marton of the Bureau's electron and ion ballistics laboratory have developed, in the electron optical analogy to the Schlieren effect, a valuable tool for the quantitative study of electrostatic or magnetic fields that are not susceptible to any other type of investigation. By means of the new technique, a dark-field image of magnetic or electric fields occurring between an electron source and a magnetic lens is formed beyond the focal plane of the lens. In this way it has been possible to obtain a visual representation of fringe fields from the small domains of spontaneous magnetization in ferromagnetic materials. The characteristics of such a pattern may then be used to compute the field distribution in the region under study. Extension of the principle provides a powerful means of broadening present knowledge concerning space-charge fields, fields produced by contact potentials, wave-guide problems, and the microstructure of metals.

The Schlieren method as applied to light rays involves the formation of an image of a light source on a convenient stop that intercepts all direct rays. If in the space between the source and lens there is a variation of the index of refraction, an image of that inhomogeneity will then be produced by means of the same lens in a conjugate plane beyond the stop. Thus a dark-field image of the variation in optical density of the refractive medium is obtained.

This method was adapted to electron-optical investigations at the Bureau in connection with the problem of measuring the magnetization of ferromagnetic wire used in the reproduction of sound and for recording data in electronic computing machinery. A magnetized wire was placed approximately 3 centimeters from a magnetic lens having a free bore of about 16 millimeters and was irradiated with an electron beam accelerated by a difference of potential of 40 kilovolts. After a magnified image of the wire was properly focused on a fluorescent screen, the direct rays were intercepted by a center stop about 1 millimeter in diameter. When the stop was placed partially across the visual field, a partly bright-field, partly dark-field image of the wire was obtained, in which the Schlieren image of the magnetic fields extending on both sides of the wire was readily recognizable. Thus, in addition to electron emission and scattering, a new category of "objects"—namely, field intensity patterns—was made available for study by means of electron-optical systems.

For a representation of ferromagnetic domains, experiments were carried out with thin laminar steel provided with a fine feather edge. After the samples were magnetized to saturation parallel to the edge, they were placed in an electron microscope, and the objective lens was slightly misalined in order to bring in one edge of the objective aperture parallel to the observed edge. In this way the direct rays were intercepted by the objective aperture, and only the electrons scattered or deflected at the edge of the specimen reached the final



The magnetic lens system of this horizontal experimental electron microscope (top) was used at the Bureau to produce a visual representation of magnetic fields by means of the electron-optical Schlieren method. From the patterns thus obtained, field intensities may be computed. In the light-optical Schlieren effect (center), an image of source *A* is formed by lens *C* on stop *D*, which intercepts all direct rays. However, rays from the source that may be scattered by an inhomogeneity *B*, occurring in the medium between the source and lens, will produce a dark-field image of this inhomogeneity on a screen at *E*.

ticSchlieren Effect

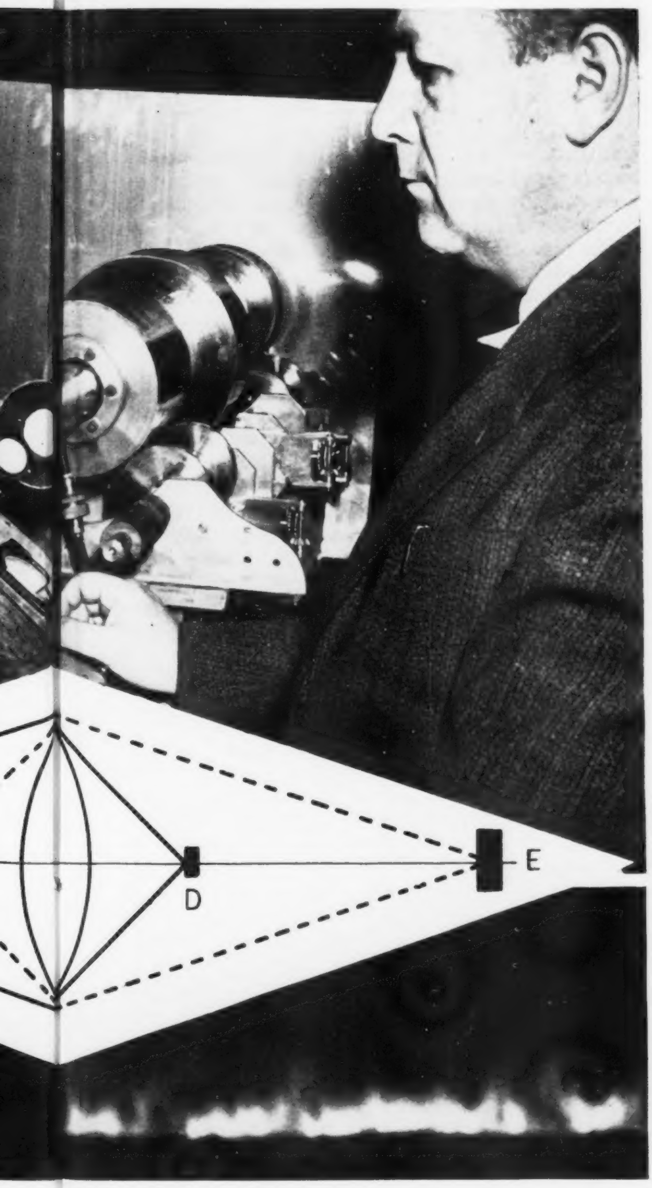
image plane to form a dark-field image.[2] The image consisted of a bright line interrupted at irregular intervals averaging a few tenths of a micron. Wherever the line was interrupted, a faint pattern was visible at right angles to the edge. This pattern was assumed to be due to the fringe field of the ferromagnetic domains or of grain boundaries. Such a pattern is produced only if the average thickness of the specimen edge in the direction of the electron beam is no greater than one domain. This observation was repeated with the objective aperture at an angle to the observed edge of the sample. Part of the image was thus dark-field, and part was a bright-field image of the magnetized edge. By overexposing the bright-field portion, a fringe pattern at right angles to the edge corresponding to that of the dark-field image was observed in the bright-field image.

[2] The micrographs were made with the cooperation of Max Swerdlow of the Bureau's electron microscopy laboratory.

Perhaps the greatest value of the electron-optical Schlieren method lies in its utility for exploring complex electric and magnetic fields of extremely small dimensions or in which a probe of size greater than the electron would disturb the field under study. In the past, calculations of the field intensity at a point have been limited to those special cases in which the geometry of the field exhibits a high degree of symmetry. However, once images of the field have been obtained by the Schlieren method, the actual intensity in the neighborhood of a sample of any shape can be computed to a good approximation from the intensity distribution of the pattern or from the apparent displacement of a deflected image. The mathematical basis for these calculations has been worked out by S. H. Lachenbruch.

For example, in a study of the field intensity about a magnetized wire the field may be assumed to be approximately that of an ideal magnetic dipole. If this assumption is made, an expected Schlieren intensity distribution based upon the theoretical trajectories of electrons approaching the wire in the midplane of a dipole can be calculated. Such a distribution may then be compared with the actual intensity variation of the Schlieren image in a line perpendicular to the image of the wire and bisecting the dipole pattern. In this way a better approximation to the field intensity in the midplane is obtained.

The use of wave guides as conductors and circuit elements in ultra-high frequency radar and communication—and more recently in some experiments in nuclear physics—often leads to arrangements whose geometry is too complicated for expression in any known system of mathematical coordinates. The electronics engineer, having in many cases only an intuitive picture of the field distribution in such parts of the guide as elbows, must rely on empirical methods in designing wave-guide techniques and equipment. Experiments being undertaken at the Bureau by D. L. Reverdin are expected to provide a method utilizing



Dark-field Schlieren image of the field of a magnetized wire (lower left). After the direct rays from an electron source have been intercepted, the rays that are deflected by the magnetized regions of the wire are collected by a magnetic lens system to form the image. When electrons scattered or deflected by a thin magnetized steel edge reach a fluorescent screen, the Schlieren image (lower right) consists of a bright line interrupted at irregular intervals by faint patterns due to the deflection of electrons by the fringe fields of the ferromagnetic domains or of grain boundaries (magnification about ×50,000).

the electron-optical Schlieren effect that may permit the calculation of field intensities in regions of a guide that are not at present susceptible to analytical treatment.

Ferromagetism offers unique possibilities for investigation of the structure and elastic properties of metals, and it has been suggested that the electron-optical Schlieren effect may prove useful in metallurgical problems of this kind. Since the direction of magnetization in a single domain of a metallic specimen, and thus the magnetic properties of the specimen as a whole, are determined by the regularity and orientation of the atomic arrangement and the interaction between electrons of neighboring atoms, any factor tending to disturb these conditions must seriously affect the ferromagnetic properties. Magnetic data subject to reliable interpretation should thus provide valuable information on metallic purity, grain orientation, and strains caused by precipitation, grain boundaries, and unequal heating or cooling. Experiments now being planned at the Bureau include a study of the behavior of the fringe-field patterns as a function of temperature up to the Curie point (at which temperature ferromagnetic substances become paramagnetic) and repetition of these measurements on a single crystal material having very large domains. An extension to ferroelectric materials is also contemplated for the purpose of checking the domain theory of such materials.

Prevention of Mildew on Leather

A fungicidal dressing for the treatment of leather goods, developed by the Bureau under the sponsorship of the Office of the Quartermaster General, provides complete protection of such goods from mildew. The growth of mildew on finished leather has previously been regarded as only a slight annoyance since, generally noticeable only during the summer months, it was believed that it caused no deterioration. Conditions in the South Pacific were, however, so favorable for its growth that it was necessary to develop preventive treatments for the use of the Armed Services personnel stationed in those areas. The Bureau's leather dressing compound has proved so effective, that it is finding widespread application and has been incorporated into various Government specifications.

The important ingredients of the new dressing are 20 percent of a mixture of equal parts of neatsfoot oil and mineral oil, for amplifying and preserving the flexible characteristics of the leather, and 2 percent of paranitrophenol, a fungicidal material for preventing the growth of mildew. The other components are 10 percent of cyclohexanone, used because of its solvent power, and 68 percent of either perchloroethylene or Stoddard's solvent. Perchloroethylene is preferred, because it is noninflammable. The compound should be applied so that the amount of the active ingredient (paranitrophenol) is not greater than 0.35 percent of the weight of the leather and should not be used for articles that make intimate contact with the skin such as hat bands and gloves.

It was not uncommon for troops in the South Pacific areas to find heavy growths of mildew appearing on their shoes overnight. Not only is it a nuisance to remove the mildew before wearing the shoes, but it has been demonstrated that the mildew weakens the leather by destroying oils that keep it flexible and soft.

Studies at the National Bureau of Standards on vegetable-tanned strap leather indicate that considerable tensile strength is lost when a heavy growth of mildew is supported on its surface. The mechanism of this loss in strength has been shown to be associated with the action of the mold-producing fungi. Thin leathers lose more strength than thick leathers, which would be expected if the action is confined to the surface. The leathers also lose oils and greases. Since chemical tests revealed that the hide substance in the leather had been only slightly affected, it is apparent that the fungi use the oils and greases as a nutrient.

The type of mold-growth most commonly found on leather is *Aspergillus niger*, often characterized by patches of white mold mixed in with the black. Known as the mycelial growth, this white mold is the vegetative stage of the mold organism. Other molds often observed if the growth of *Aspergillus niger* is not too luxuriant are various species of *Penicillium* and a yellow growth of *Aspergillus oryzae*.

That the growth of mold depends upon the type of leather and its previous treatment was also shown in the Bureau investigation. Chrome-tanned leather grows mildew much less readily than vegetable-tanned sole leather. Chrome-retanned and vegetable-tanned strap leather are intermediate, with the latter growing mold more profusely than the former. Leathers that contain greases grow mold much more readily than those which contain no grease. Vegetable-tanned sole leather is most susceptible to mildew, because it is finished with a small amount of glucose and magnesium sulfate. Other factors that favor mold growth on leather are vegetable tannage and high grease content.

The Bureau's formula for fungicidal leather dressing, incorporated in a specification[3] by the Office of the Quartermaster General, is now being used for the treatment of shoes and other leather items that are to be placed in storage, as well as for reconditioning combat boots that have become mildewed and stiffened in storage. It has also been approved by the Technical Committee on Leather and Leather Products for promulgation as a Federal specification.

The fact that mildew was a particularly difficult problem in the South Pacific areas is evidence that mold growth is a function of atmospheric conditions. Accordingly, practical experiments were conducted that demonstrated that mildew would not grow on leather in an atmosphere having a relative humidity less than 85 percent, at a temperature suitable for mold growth. Packaging tests followed, and it was found that if

[3] U. S. Army Specification: Compound, Leather Dressing, Preservative for Field Treatment No. 92-61.

A new fungicidal dressing developed at the Bureau provides complete protection of leather goods against mildew. Most common of the types of mold-growth found on leather is *Aspergillus niger*, often characterized by patches of white mold known as the *mycelial* growth.

leather were properly sealed to prevent absorption of moisture from the air, mildew would be prevented.

Another simple, practical procedure for preventing growth in a closed space is to raise the temperature slightly in order to produce a relative humidity below that necessary to support mold growth. The procedure may be applied satisfactorily in small spaces, such as closets or bookcases, where the heat from a 60- or 100-watt light bulb is usually sufficient.

Further proof of the need for moisture-proof packaging, in addition to the fungicidal dressing, was obtained. A study of the influence of mildew-growing conditions on leather showed that permanent deterioration of the leather is caused by the combination of high temperature and high relative humidity that promote the growth of mildew. Therefore, when leather is stored for a long time or shipped through tropical regions, the use of both moisture-proof packaging and the Bureau's fungicidal dressing seems desirable. When leather is used in the tropics, the new fungicidal dressing should lengthen its life by preventing mildew.

Cathodic Protection of Underground Structures

A study of some of the factors involved in electrical protection against underground corrosion [4] has been made by I. A. Denison and Melvin Romanoff of the Bureau. In six of a total of eight test sites, corrosion of steel specimens was adequately prevented over test periods ranging from 3 to 6 years by connecting zinc cylinders to the steel. It was found that the current required to prevent the corrosion of steel electrolytically was approximately equal to the current associated with normal corrosion and hence could be taken as a measure of the corrosion rate in the soils studied. From this it would appear that cathodic protection is, under ideal conditions, a highly efficient means of combatting corrosion of steel, since all of the applied current is utilized in eliminating the local corrosion circuits.

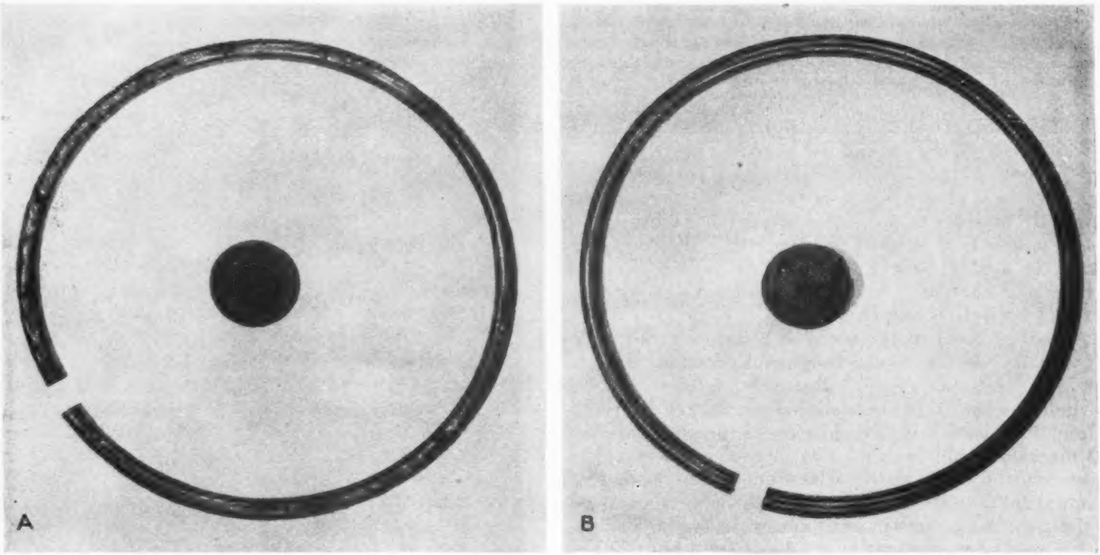
Corrosion in the soil, as in most natural environments, is often caused by differences in potential of local areas on the corroding surface. Those areas whose potentials with respect to conventional reference electrodes are relatively high are designated as anodes, and areas of lower potential are known as cathodes. Because the electric current associated with corrosion flows toward, rather than from, the cathodic areas, they are not subject to corrosion, as are the anodic areas. Now, if sufficient current is caused to flow from an external source toward the corroding surface, the potential difference between the local anodic and cathodic areas, and consequently the cause of corrosion, is eliminated. This principle, the basis of cathodic protection, is widely and effectively applied to protect underground pipe lines from the corrosive action of soils.

If electric power is available, a cathodic protection unit can be economically installed; but pipe lines transporting oil, gasoline, and natural gas over vast distances often traverse areas of corrosive soils so remote from sources of power that the installation cost of cathodic protection, including the expense of rectifiers, may be great. Fortunately, a source of energy for cathodic protection in such areas can be provided by the galvanic corrosion of bars of the electronegative metals, zinc, magnesium, or aluminum, buried at suitable intervals along the right of way and connected to the pipe line.

In order to investigate the behavior of zinc anodes for cathodic protection in various types of soils, the Bureau in 1941 initiated a series of field tests in cooperation with pipe line companies, in which experimental zinc-steel couples were installed at eight test sites. The cathode of the experimental couple was a small steel ring, to which were connected either one, two, or three cylindrical zinc anodes, giving ratios of the area of steel to zinc of 20, 10, and 6.7, respectively. By varying these ratios, the current density on the corresponding cathodes was subject to some control. Unconnected steel rings and zinc cylinders were also buried at each test site.

After periods of operation ranging from 3 to 6 years, the units were removed from the test sites, and the extent of cathodic protection provided was determined. In six of the eight soils in which the couples were installed, satisfactory protection was obtained. Although

[4] For further technical details see, Behavior of experimental zinc-steel couples underground, by Irving A. Denison and Melvin Romanoff, J. Research NBS **40**, 301 (1948) RP1876.



In field tests carried out by the Bureau, effective cathodic protection against underground corrosion was afforded to steel specimens by zinc anodes connected to the steel. Compare the steel rings and the zinc cylinders of specimens after simultaneous exposure in the same test site for 3 years: (left) Unconnected steel ring and zinc cylinder; (right) steel ring coupled to zinc anode.

a zinc-steel area ratio of 1:20 was sufficient for protection at three of these sites, an area ratio of 1:10 was required at the other three. At the other two sites high resistivity and high alkalinity of the soil tended to reduce the current output of the zinc anodes to such an extent that cathodic protection was not obtained. However, it is probable that both of these unfavorable conditions could be counteracted by surrounding the zinc anodes with a salt, such as calcium sulfate, which would not only increase the conductivity of the soil but would also prevent the formation of insoluble films or deposits of corrosion products on the zinc surface.

In addition to measurements of loss in weight of the steel rings and of the zinc cylinders, and of maximum depth of penetration of the steel rings at the conclusion of the field tests, galvanic currents and electrode potentials were measured at intervals during the course of the tests. The average value of the galvanic current, which was just sufficient to prevent corrosion, was found to be approximately equal to the average current associated with the normal corrosion of the unconnected steel rings. Hence, to prevent corrosion in the localities studied, it is necessary simply to apply a current equal to that discharged from the local anodic areas.

In the protection of pipe lines electrolytically, it is obviously desirable to be able to measure accurately the current that will just protect a given area. Otherwise, the pipe line may be incompletely protected; or, in the event of overprotection, expensive power may be wasted, with possible damage to adjacent structures on which the excess current would tend to collect and discharge. Estimation of the current required for protection of underground structures of iron or steel is generally based on empirical procedures, none of which can be said to have theoretical justification. In an effort to establish a more scientific method for determining this current, a procedure suggested a number of years ago by the Bureau was followed. The potential of the steel rings was measured as increasing currents were caused to flow toward the rings from an external source. At low currents the potentials of the rings remained constant; but after some transition, the potentials were observed to increase linearly with the logarithm of the applied current. The value of the applied current that was just sufficient to prevent corrosion of the cathodes was found to be indicated approximately by the departure of the potential from the constant value at low currents.

Underground Corrosion Exhibit

In connection with comparative field tests of the corrosion resistance of various pipe materials in different types of soils, the National Bureau of Standards has announced an exhibit of approximately 3,000 actual test specimens. Chemists, metallurgists, corrosion engineers, and others interested in the behavior of materials underground are invited to inspect the test samples, which will be on display until August 15, 1948, in the Bureau's Underground Corrosion Laboratory.

The specimens were exposed at 15 test sites throughout the United States for periods ranging from 5 to 14 years. They consist of 85 varieties of materials, including 7 types of wrought iron and wrought alloys; 17

types of cast iron and cast alloys; 22 types of steel and steel alloys; 13 types of copper and copper alloys; and miscellaneous samples of lead, zinc, metallic- and non-metallic-coated pipe, and asbestos-cement pipe. Measurements of loss of weight and depth of pitting of the specimens have been made, and a report on the corrosion resistance shown by the materials studied is in preparation.

Control of Fading Lamps With Light-Sensitive Paper

A practicable, inexpensive, and yet reliable means of controlling the performance of fading lamps has been developed in the Bureau's textiles laboratory, in cooperation with members of the paper laboratory, as a solution to problems arising from the lack of reproducibility among such lamps. This is accomplished by the use of a special light-sensitive paper, which, when placed in the lamp with commercial materials being tested, will fade to an endpoint that can be visually matched with a standard. A very simple method of control, independent of the unavoidable variation of radiant energy output of fading lamps, is thus provided.

The use of arc lamps to test the light-stability of commercial products has become accepted procedure in many branches of industrial production and research. It is estimated that between one and two thousand irradiation units are in practically constant operation. The results are often used to assess the relative, and even absolute, light-stability of materials used in very large-scale applications. It is therefore important that such arc lamps operate reliably.

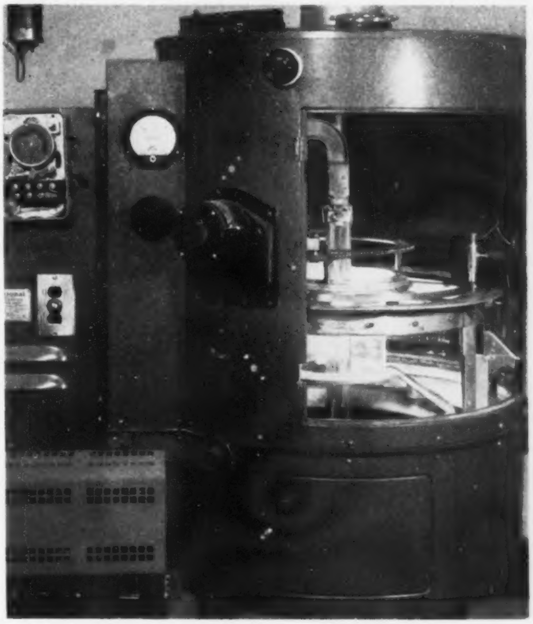
With increasing use of irradiating units, however, it has become apparent that these arcs do not function reproducibly from unit to unit or in a given unit from day to day. As a result of recent surveys it has been determined that the variations in performance of the same make of lamp are often quite large. Among textile fading lamps, which can be considered typical, some of the weakest lamps required from two to three times as long to produce the same fading as the strongest lamps. Over one-third of the lamps included in the group was found to deviate by more than 15 percent from a mean value.

There are a variety of explanations for such behavior, but the most generally applicable one is variation of line voltage. The radiant energy output in the 300- to 400-millimicron range, which is perhaps for most applications the most effective region of the glass enclosed arc, is decreased 11 percent by a 4-percent drop in line voltage. Voltage variations at most substations in the District of Columbia are about 4 percent, which are probably smaller than in most communities because of the limited amount of heavy manufacturing in the District. To this must be added the variable voltage drop in the mains, transformers, and individual plant wiring, which may be as high as 11 percent. It is thus apparent that voltage difficulties can account for very large differences in lamp performance. Although the irradiating units are provided with transformer or rheostat taps for matching line voltages, the latter are difficult to measure without a recording voltmeter, and even then are subject to change after measurement. The taps, furthermore, may not adequately match the mean line voltage.

It is obvious that solving line-voltage problems as a means of securing uniform arc lamp behavior would be difficult. An attempt has therefore been made to develop a simple, reliable method of gaging the performance of arc lamps by the use of light-sensitive papers. Several papers have been prepared especially for this purpose in the Bureau's experimental mill.

These papers are permanent in the dark and can be produced in large uniform batches. In use, a piece of the test paper is placed in the lamp along with the materials to be irradiated, and exposure is continued until the test paper matches a standard exposure of, for example, 20 "standard fading hours," regardless of the actual time elapsed.

The standard fading hour now under trial was recommended by the committees on colorfastness to light of textiles of the American Association of Textile Chem-



Accurate control of fading lamps is attained by means of light-sensitive papers that have had a standard exposure in the Bureau's standard fading lamp. The paper is wrapped around an accurately machined drum that rotates about the arc during standardization.

ists and Colorists, and of the American Society for Testing Materials. It is considered to be in agreement with the Fade-Ometer hour used by the dyestuff and textile industries for a number of years for rating colorfastness to light of dyed textiles. The newer Fade-Ometers are somewhat faster in their fading action than those on which the concept of the Fade-Ometer hour was developed.

The standard exposures are produced from the same batch of paper by exposing it to the Bureau's standard fading lamp. This lamp has been developed as a means of obtaining accurately measured, definite dosages of radiant energy under reproducible conditions. The light-quantities are measured with "photon counters," light-integrating meters adapted for high-intensity sources. The standard exposures are permanent in the dark and change negligibly during a year's normal use. They are mounted in strip form in a protecting booklet along with plus and minus 10-percent steps, to allow the user to estimate the degree of overexposure or to anticipate the end of the period.

The use of light-sensitive paper should make it possble to set up more rigid specifications of light-stability for all materials where this property is important. The work of the Bureau is still in the experimental stage. Neither the paper thus far developed nor the lamp used in standardization is considered to be the final form of this method for lamp control. In fact, there have been requests from diverse industries for papers useful for controlling exposures over much shorter and longer periods of time, and for use in lamps with water spray. The experience gained from this work has pointed the way toward more sensitive papers of wider scope. Papers useful over exposure periods lasting a few hours to a week are now under development, and the radiometric technique is being improved.

NBS Publications

Periodicals [5]

Journal of Research of the National Bureau of Standards, volume **40**, number 6, June 1948. (RP1887 to RP1895, inclusive.)

Journal of Research of the National Bureau of Standards, volume **39**, Title page, corrections, and contents, July to December 1947. (RP1807 to RP1849, inclusive.) 5 cents.

Technical News Bulletin, volume **32**, number 6, June 1948. 10 cents.

CRPL–D46. Basic Radio Propagation Predictions for September 1948. Three months in advance. Issued June 1948. 10 cents.

Nonperiodicals

Research Papers [5, 6]

RP1879. Measurement of the slipperiness of walkway surfaces. Percy A. Sigler, Martin N. Geib, and Thomas H. Boone. 10 cents.

RP1880. Perforated cover plates for steel columns: Summary of compressive properties. Ambrose H. Stang and Martin Greenspan. 10 cents.

RP1881. Changes in the indices of refraction and liquidus of a barium crown glass produced by the partial substitution of some oxides. Edgar H. Hamilton, Oscar H. Grauer, Zeno Zabowsky, and C. H. Hahner. 10 cents.

RP1882. Influence of low temperatures on the mechanical properties of 18:8 chromium-nickel steel. D. J. McAdams, Jr., G. W. Geil, and Frances Jane Cromwell. 10 cents.

RP1883. Absorption of X-rays in air. Frank H. Day and Lauriston S. Taylor. 10 cents.

RP1884. Location of the galvanometer branch for maximum sensitivity of the Wheatstone bridge. F. Ralph Kotter. 10 cents.

RP1885. Second dissociation constant of oxalic acid from 0° to 50°C, and the pH of certain oxalate buffer solutions. Gladys D. Pinching and Roger G. Bates. 10 cents.

RP1886. Pyrolytic fractionation of polystyrene in a high vacuum and mass spectrometer analysis of some of the fractions. Samuel L. Madorsky and Sidney Straus. 10 cents.

Commercial Standards [5]

CS60–48. Hardwood dimension lumber. (Second edition. Supersedes CS60–36.) 10 cents.

Handbooks [5]

H30. National electrical safety code. Grounding rules and parts I, II, III, IV, and V. (Supersedes H3.) $1.25.

Letter Circulars [7]

LC901. The fundamental basis for the standardization of electrical instruments and meters.

LC902. Building Materials and Structures Reports published by the National Bureau of Standards. (Supersedes LC800.)

LC903. Electrodeposition: Publications by the staff of the National Bureau of Standards. (Supersedes LC881.)

LC904. Electric batteries and standard cells: Publications by the staff of the National Bureau of Standards and references to other sources of information. (Supersedes LC846.)

LC905. Standards to promote export trade. (Supersedes LC799.)

LC906. Standard fading lamp and method of calibrating lamps used in testing colorfastness to light.

LC907. Textile testing equipment.

Articles by Bureau Staff Members in Outside Publications [8]

Standard cells and the change from International to Absolute electrical units. George W. Vinal. J. Electrochem. Soc. (235 West One Hundred Second St., New York 25, N. Y.) 93, No. 4, 95 (April 1948).

Microwave attenuation standards. R. E. Grantham and J. J. Freeman. Elect. Eng. (500 Fifth Avenue, New York 18, N. Y.) 67, 535 (1948).

Microwave frequency standards. B. R. Husten and Harold Lyons. Elec. Eng. 67, 436 (1948).

Resin bonding and strength development in offset papers. Charles G. Weber, Merle B. Shaw, Martin J. O'Leary, and Joshua K. Missimer,Paper Ind. & Paper World (59 East Van Buren Street, Chicago 5, Ill.) 30, No. 1, 83 (April 1948).

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[5] Send orders for publications under this heading only to the Superintendent of Documents, Government Printing Office, Washington 25, D. C. Annual subscription rates: Journal of Research, $4.50 (foreign $5.50); Technical News Bulletin, $1 (foreign $1.35); Basic Radio Propagation Predictions, $1 (foreign $1.25). Single copy prices of publications are indicated in the lists.

[6] Reprints from May Journal of Research.

[7] Available on request from the National Bureau of Standards, Washington 25, D. C. Letter Circulars are prepared to answer specific inquiries addressed to the Bureau, and are sent only on request to persons having a definite need for the information. The Bureau cannot undertake to supply lists or complete sets of letter circulars or send copies automatically as issued.

[8] These publications are not available from the Government. Requests should be sent direct to the publishers.

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